

UNCLASSIFIED

This document consists of 171 pages

No. 70 of 185 copies, Series A

Report to the Test Director

BLAST MEASUREMENTS

Operation Tumbler-Snapper

Edited by

F. B. Porzel

Los Alamos Scientific Laboratory
University of California
August 1952

UNCLASSIFIED

DISTRIBUTION STATEMENT A

Approved for public release

Distribution Unlimited

SEP 12 1995

F

19950906 116

DISTRIBUTION STATEMENT A APPLIES
PER NTPR REVIEW.

DATE

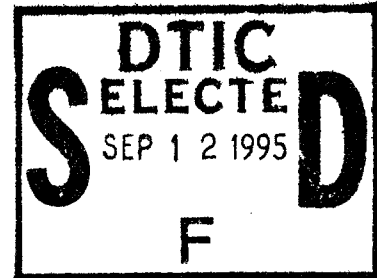
6/20/95

Figures 6.14 to 6.19 on pages 69 to 73 are not in sequence.

UNCLASSIFIED

This document consists of 171 pages

No. 70 of 185 copies, Series A



Report to the Test Director

BLAST MEASUREMENTS

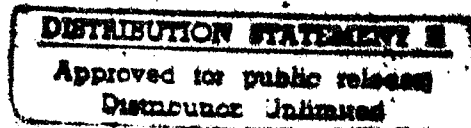
Operation Tumbler-Snapper

Edited by

F. B. Porzel

Accession For	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

Los Alamos Scientific Laboratory
University of California
August 1952



UNCLASSIFIED

UNCLASSIFIED

CONTENTS

	Page
Part I—Blast-wave Material-velocity Measurements (Projects 19.2a and b)	
ABSTRACT	15
ACKNOWLEDGMENTS	17
CHAPTER 1 OBJECTIVES	19
1.1 Methods of Labeling Air	19
1.2 Material-velocity Method of Pressure Measurement	19
1.3 Additional Information	19
CHAPTER 2 BACKGROUND	20
2.1 Résumé of Previous Work	20
2.1.1 General Analytical Method	20
2.1.2 Mortars and JATO's	20
2.2 Feasibility Test of High-altitude Measurements	20
2.3 Description of Basic Instruments	25
CHAPTER 3 OPERATIONS	26
3.1 Division of Responsibility	26
3.2 Antiaircraft-gun Battery	26
3.3 Safety Engineering	26
CHAPTER 4 INSTRUMENTATION	27
4.1 Summary	27
4.2 Description of Instrumentation	28
4.2.1 Location	28
4.2.2 Mortars and JATO's	28
4.2.3 90-mm Guns	28
4.2.4 Cameras	37
4.2.5 Reliability	37
CHAPTER 5 RESULTS	38
5.1 Analysis	38
5.1.1 Film	38
5.1.2 Meteorological Data	40

UNCLASSIFIED

UNCLASSIFIED

CONTENTS (Continued)

	Page
5.2 Pressure vs Distance	40
5.3 Time of Arrival	40
CHAPTER 6 ANALYSIS OF DATA	52
6.1 Pressure vs Distance	52
6.1.1 Summary	52
6.1.2 Tumbler Shot 1	52
6.1.3 Tumbler Shot 2	53
6.1.4 Tumbler Shots 3 and 4	53
6.1.5 Tumbler-Snapper Shots 5 and 8	53
6.2 Time of Arrival	53
6.3 Further Data Available on Films	54
6.3.1 Triple Point	54
6.3.2 Shock Wave	54
6.3.3 Thermal Shock	64
6.3.4 Dust	64
6.3.5 Miscellaneous	74
CHAPTER 7 CONCLUSIONS	75
7.1 Reliability of Data	75
7.2 Scatter	75
7.3 Errors	75
CHAPTER 8 RECOMMENDATIONS	78
8.1 Cameras	78
8.2 Methods	78
APPENDIX A TYPICAL ANALYSIS OF MORTAR-JATO FILM (EG&G 13073)	79
APPENDIX B TYPICAL ANALYSIS OF GUN-BURST FILM (EG&G 13470)	90

Part II—Beta-densitometer Feasibility Test

(Project 19.2c)

ABSTRACT	99
CHAPTER 1 INTRODUCTION	101
CHAPTER 2 INSTRUMENTATION	102
2.1 Alternating-current System	102
2.2 Direct-current System	102
2.3 Calibration	102

UNCLASSIFIED

CONTENTS (Continued)

	Page
CHAPTER 3 PRINCIPAL MODIFICATIONS INCORPORATED IN DENSITOMETER DESIGNED FOR TUMBLER	110
3.1 General	110
3.2 Alternating-current System	111
3.3 Direct-current System	111
CHAPTER 4 RESULTS	112
CHAPTER 5 CONCLUSIONS	118
CHAPTER 6 RECOMMENDATIONS	119

Part III—Interferometer-gauge Pressure-Time Measurements (Project 19.2d)

ABSTRACT	123
CHAPTER 1 INTRODUCTION	125
1.1 General Discussion	125
1.2 Secondary Problems	125
CHAPTER 2 APPARATUS	126
2.1 General Discussion	126
2.2 Gauge Mounting	126
2.3 Control	126
2.4 Film-speed Determination	129
2.5 Power	129
2.6 Oil-filled Pressure-transmission Lines	129
2.7 Installation Data	129
CHAPTER 3 PROCEDURE AND INSTALLATION	130
3.1 General	130
3.2 Snapper 1 Installations	130
3.3 Installations, Shots 2 to 4	135
3.4 Recovery of Records	135
3.5 Analysis of Data	135
CHAPTER 4 RESULTS	136
4.1 General	136
4.2 Oil Line	136
4.3 Control Apparatus and Mounts	136



CONTENTS (Continued)

	Page
CHAPTER 5 DISCUSSION OF RESULTS	145
5.1 Air Transmission Lines	145
5.2 Oil Transmission Lines	145
5.3 Installations	146
CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS	147

**Part IV—The Measurement of Preshock Sound Velocity
(Project 19.2f)**

ABSTRACT	151
CHAPTER 1 INTRODUCTION	153
1.1 Purpose	153
1.2 Discussion	153
CHAPTER 2 METHOD OF MEASUREMENT	154
2.1 Description of Measurement	154
2.2 Description of Apparatus	154
CHAPTER 3 RESULTS	162
CHAPTER 4 CONCLUSIONS	168

ILLUSTRATIONS

**Part I—Blast-wave Material-velocity Measurements
(Projects 19.2a and b)**

CHAPTER 2 BACKGROUND	
2.1 JATO Construction	21
2.2 Mortar, Canister, and Fuze: Components	22
2.3 Assembled Mortar Unit	23
2.4 90-mm Antiaircraft Gun	24
CHAPTER 4 INSTRUMENTATION	
4.1 Blast Line, Frenchman Flat	29
4.2 Blast Line and Gun Station, Area 7	30
4.3 Gun Station, Tumbler-Snapper Shots 5 and 8	31
4.4 Mortar-JATO Timing and Power Circuit	32



ILLUSTRATIONS (Continued)

	Page
4.5 90-mm Antiaircraft-gun "Electro-Mechanical" Firing System	33
4.6 Planned Gun Bursts, Tumbler Shot 2	34
4.7 Planned Gun Bursts, Tumbler Shot 3	35
4.8 Planned Gun Bursts, Tumbler Shot 4	36

CHAPTER 5 RESULTS

5.1 Material Velocity vs Distance, Tumbler Shots 1 and 2	42
5.2 Material Velocity vs Distance, Tumbler Shots 3 and 4	43
5.3 Material Velocity vs Distance, Tumbler-Snapper Shots 5 and 8	44
5.4 Pressure vs Distance, Tumbler Shots 1 and 2	45
5.5 Pressure vs Distance, Tumbler Shots 3 and 4	46
5.6 Pressure vs Distance, Tumbler-Snapper Shots 5 and 8	47
5.7 Time of Arrival, Tumbler Shots 1 and 2	49
5.8 Time of Arrival, Tumbler Shots 3 and 4	50
5.9 Time of Arrival, Tumbler-Snapper Shots 5 and 8	51

CHAPTER 6 ANALYSIS OF DATA

6.1 Early Mortar-JATO, Tumbler Shot 4, Station 203cc, 5 msec After Zero Time	55
6.2 Mortar-JATO and Dust Skirt, Tumbler Shot 4, Station 203cc, 900 msec After Zero Time	56
6.3 Mortar-JATO and Dust Skirt, Tumbler Shot 4, Station 203cc, 1220 msec After Zero Time	57
6.4 Mortar-JATO and Dust Skirt, Tumbler Shot 4, Station 203cc, 1480 msec After Zero Time	58
6.5 JATO and Condensation Cloud, Tumbler Shot 4, Station 203cc, 2530 msec After Zero Time	59
6.6 JATO and Condensation Cloud, Tumbler Shot 4, Station 203cc, 2815 msec After Zero Time	60
6.7 Early Mortar-JATO, Tumbler Shot 1, Stations F-204cc and F-205cc, 9 msec Before Zero Time	61
6.8 Incident and Reflected Shocks, Tumbler Shot 1, Stations F-204cc and F-205cc, 775 msec After Zero Time	62
6.9 Early Mortar-JATO, Tumbler Shot 1, Station F-209cc, 27 msec Before Zero Time	63
6.10 Mortar-JATO During Motion, Tumbler Shot 2, Station 202, 1060 msec After Zero Time	65
6.11 Thermal Shock, Tumbler Shot 4, Station 202cc, 440 msec After Zero Time	66
6.12 Thermal and Reflected Shocks, Tumbler Shot 4, Station 202cc, 500 msec After Zero Time	67
6.13 Early Mortar-JATO, Tumbler Shot 4, Station 202cc, 5 msec After Zero Time	68
6.14 "Before-and-After" Outline	69
6.15 Selected Shock Contours	70
6.16 Preshock Dust, Tumbler Shot 1, Stations F-204cc and F-205cc, 575 msec After Zero Time	71
6.17 Mortar-JATO Prior to Shock Arrival, Tumbler Shot 1, Station F-209cc, 1045 msec After Zero Time	72

ILLUSTRATIONS (Continued)

	Page
6.18 Gun Bursts 1 and 2 and Parachute Gauge, Tumbler-Snapper Shot 5, 220 msec After Zero Time	73
6.19 Gun Burst 3 and Parachute Gauge, Tumbler-Snapper Shot 5, 32 msec After Zero Time	73

APPENDIX A TYPICAL ANALYSIS OF MORTAR-JATO FILM (EG&G 13073)

A.1 Smoke-puff Contours	80
A.2 Station F-202cc (Plan)	80
A.3 Station F-202cc (Elevation)	81
A.4 Displacement vs Frame Number	83
A.5 Geometrical Camera-Object Relation	85
A.6 Obliquity Effect	86
A.7 Determination of True Line of Motion	86
A.8 Effect of Obliquity on Tower Separation	88

APPENDIX B TYPICAL ANALYSIS OF GUN-BURST FILM (EG&G 13470)

B.1 Planned and Actual Burst Positions	91
B.2 Camera-Gun-burst Geometry	92
B.3 Effect of Range Error	92
B.4 Displacement vs Frame Number	94

Part II—Beta-densitometer Feasibility Test

(Project 19.2c)

CHAPTER 2 INSTRUMENTATION

2.1 Arrangement of A-c Beta Densitometer, Operation Tumbler	103
2.2 Block Diagram of A-c Beta Densitometer	104
2.3 Detailed Circuit Diagram, A-c Densitometer	105
2.4 Alternating-current Beta-densitometer Load and Coupling Circuit	106
2.5 Arrangement of D-c Beta Densitometer, Operation Tumbler	106
2.6 Block Diagram of D-c Beta Densitometer	107
2.7 Detailed Circuit Diagram, D-c Beta Densitometer	108
2.8 Gamma-balancing, Filter, and Biasing Circuits, A-c Beta Densitometer	109
2.9 Circuit for Calibration Foil Release System	109

CHAPTER 4 RESULTS

4.1 Density of Dust-loaded Air as a Function of Time, Station 7-205aa, GR = 3750 Ft, Height of Burst = 1100 Ft	113
4.2 Density of Dust-loaded Air as a Function of Time, Station 7-208aa, GR = 6000 Ft, Height of Burst = 1100 Ft	114
4.3 Density of Dust-loaded Air as a Function of Time, Station 7-205aa, GR = 3750 Ft, Height of Burst = 3450 Ft	115

ILLUSTRATIONS (Continued)

	Page
4.4 Density of Dust-loaded Air as a Function of Time, Station 7-208aa, GR = 6000 Ft, Height of Burst = 3450 Ft	116
4.5 Density of Dust-loaded Air as a Function of Time, Station 7-205aa, GR = 3750 Ft, Height of Burst = 1040 Ft	117

Part III—Interferometer-gauge Pressure-Time Measurements (Project 19.2d)

CHAPTER 2 APPARATUS

2.1 Oil-filled Pressure-transmission Line for Interferometer Gauge	127
--	-----

CHAPTER 3 PROCEDURE AND INSTALLATION

3.1 Completed Gauge Installation, Station F-209	131
3.2 Removal of Shielding, Station F-209	132
3.3 Mounted Gauge and Control and Power Box, Station F-209	133
3.4 Power and Control Box, Station F-209	134

CHAPTER 4 RESULTS

4.1 Interferometer-gauge Pressure vs Time Graph, Snapper 1, Station 205, 7-in. Air Line	137
4.2 Interferometer-gauge Pressure vs Time Graph, Snapper 1, Station 207, 5-in. Air Line	138
4.3 Interferometer-gauge Pressure vs Time Graph, Snapper 1, Station 209, 5-in. Air Line	139
4.4 Interferometer-gauge Pressure vs Time Graph, Snapper 2, Station 203, 7-in. Oil Line	140
4.5 Interferometer-gauge Pressure vs Time Graph, Snapper 2, Station 205, 5-in. Oil Line	141
4.6 Interferometer-gauge Pressure vs Time Graph, Snapper 3, Station 203, 7-in. Oil Line	142
4.7 Interferometer-gauge Pressure vs Time Graph, Snapper 3, Station 209, Flush Gauge	143
4.8 Interferometer-gauge Pressure vs Time Graph, Snapper 4, Station 207, 3-in. Oil Line	144

Part IV—The Measurement of Preshock Sound Velocity (Project 19.2f)

CHAPTER 2 METHOD OF MEASUREMENT

2.1 Block Diagram of Sonic Oscillator	155
2.2 Sonic Oscillator Circuit	156
2.3 Timing-marker Circuit	157

ILLUSTRATIONS (Continued)

	Page
2.4 "Zero" Time Marker Circuit	157
2.5 Relay Network	158
2.6 Instrument Can and Recording Station	159
2.7 Transmitter-Microphone Mounts	160

CHAPTER 3 RESULTS

3.1 Record of the Temperature Rise, Tumbler 4	163
3.2 Air Temperature vs Time (Preshock), Sonic Oscillator, Tumbler 2, Station 238, GR 262	164
3.3 Air Temperature vs Time (Preshock), Sonic Oscillator, Tumbler 3, Station 5, GR 3653	165
3.4 Temperature vs Time (Preshock), 1 Ft Above Ground, Station 7-202, 1344 Ft from Zero, Tumbler 4	166
3.5 Temperature vs Time (Preshock), Sonic Oscillator, 1 Ft Above Ground, Station 7-205, 3589 Ft from Zero, Tumbler 4	167

TABLES

Part I—Blast-wave Material-velocity Measurements (Projects 19.2a and b)

CHAPTER 4 INSTRUMENTATION

4.1 Numbers and Types of Instrumented Stations	27
4.2 Instrumentation by Stations	28

CHAPTER 5 RESULTS

5.1 Summary of Photographic Results	38
5.2 Burst Coordinates (Deviation from Planned Ground Zero)	39
5.3 Meteorological Data	40
5.4 Slant Range, Material Velocity, and Peak Pressure	41
5.5 Times of Arrival	48

APPENDIX A TYPICAL ANALYSIS OF MORTAR-JATO FILM (EG&G 13073)

A.1 Displacement vs Frame Number (Mortar Puff, Station 202cc)	82
---	----

APPENDIX B TYPICAL ANALYSIS OF GUN-BURST FILM (EG&G 13470)

B.1 Displacement vs Frame Number (Tumbler-Snapper 5, Burst 2)	93
---	----

TABLES (Continued)

	Page
Part III—Interferometer-gauge Pressure-Time Measurements (Project 19.2d)	
CHAPTER 2 APPARATUS	
2.1 Gauge Data	128
CHAPTER 3 PROCEDURE AND INSTALLATION	
3.1 Gauge Locations and Shielding	130
CHAPTER 5 DISCUSSION OF RESULTS	
5.1 Comparison of Results	145
Part IV—The Measurement of Preshock Sound Velocity (Project 19.2f)	
CHAPTER 3 RESULTS	
3.1 Table of Temperatures	162

Part I

**BLAST-WAVE MATERIAL-VELOCITY
MEASUREMENTS (PROJECTS 19.2a AND b)**

by

Daniel F. Seacord, Jr.

ABSTRACT

The Operation Tumbler-Snapper material-velocity experiments were instrumented in a manner similar to that used on Operation Buster-Jangle. Methods of labeling air for photographic recording consisted of mortars and JATO's. In addition, the firing of high-altitude smoke projectiles from guns was included as a feasibility test for similar instrumentation on Operation Ivy.

Tumbler shots 1 to 4 and Tumbler-Snapper shots 5 and 8 were instrumented, and data were obtained on all shots. This part of the report discusses the analysis of data for peak material velocity and overpressure as a function of distance. Further data on time of arrival and thermal shock waves are presented; the latter are in preliminary form. Additional photographic records, not yet analyzed, are discussed, and the extent and value of such future analyses are briefly described.

Two appendixes present the analytical method of data reduction in detail.

~~SECRET INFORMATION~~


ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of the following officer and men assigned to the project by the Anti-Aircraft Artillery and Guided Missile Center, Fort Bliss, Texas, for installation and maintenance of the 90-mm antiaircraft battery:

Paul B. Barbour, 1st Lt (Artillery)
M/Sgt Rafael L. Tafoya
Cpl Jack C. Campbell
Cpl Gabriel G. Casley
Cpl William W. Freeman
Cpl Frank B. Luchini
Cpl Richard L. Ring

Without the photographic services of Edgerton, Germeshausen & Grier, the extent of the experiment would have been severely limited.

~~SECRET INFORMATION~~



CHAPTER 1

OBJECTIVES

1.1 METHODS OF LABELING AIR

The feasibility of the material-velocity (or "mass-motion") method of measuring peak overpressures associated with a nuclear detonation was demonstrated in Operation Buster-Jangle. The two air-labeling methods there employed (mortars and JATO's) were again used on Operation Tumbler but on a much larger scale. A larger number of stations were instrumented, and there was greater camera coverage by Edgerton, Germeshausen & Grier (EG&G). In addition, a third method of labeling the air for photographic recording was employed. It was essentially a feasibility test for Operation Ivy, but when employed on two shots of Operation Snapper it also provided an independent pressure measurement for calibration of the parachute gauges of Project 1.1. This method involved firing a 90-mm smoke projectile, fuzed to burst at an altitude (1) comparable to the height of bomb burst for the airdrops and (2) above the burst height for the two tower shots on which the method was employed.

1.2 MATERIAL-VELOCITY METHOD OF PRESSURE MEASUREMENT

In relation to the over-all blast-measurement program, the material-velocity method of^a pressure measurement provided (1) data in a region not covered by other instrumentation and (2) an independent method of pressure measurement in the regions so instrumented. The region of 100 to 300 ft above the blast line was covered by mortar bursts and JATO columns, whereas the experiments conducted by other projects along the blast line were limited to altitudes of 50 ft. The 90-mm gun bursts provided information at and above the altitude of the bomb burst; thus additional data in the region covered by the rockets of Project 1.5 were provided by an independent method.

1.3 ADDITIONAL INFORMATION

Although the present report is concerned solely with the determination of peak overpressure as a function of distance, the material-velocity method is a means of studying many of the hydrodynamic variables associated with the blast wave. Future analysis of the data on hand from Operations Buster-Jangle and Tumbler-Snapper can eventually result in a detailed "blue-print" of the blast wave as a function of time.

CHAPTER 2

BACKGROUND

2.1 RÉSUMÉ OF PREVIOUS WORK

2.1.1 General Analytical Method

The development of the material-velocity method of measurement of the hydrodynamic variables associated with a nuclear explosion has been discussed in the J-10 Buster-Jangle report.¹ The following is a brief description of the general method. Parcels of air are labeled with smoke, and the motion of this visible cloud, when struck by the blast wave, is then re-recorded photographically. Analysis of the film provides data on the displacement of the smoke cloud, and, with the known camera speed, a displacement-time curve may be drawn. The material velocity associated with the peak overpressure of the blast wave is taken to be the maximum slope of the displacement-time curve. This velocity, u , together with values of ambient sound velocity, c_0 , and ambient pressure, P_0 (from meteorological soundings), when applied to the proper Rankine-Hugoniot equation,* permits the calculation of the peak overpressure, P . From knowledge of the location of the smoke clouds in relation to the bomb-detonation point, a pressure-distance curve may be derived.

2.1.2 Mortars and JATO's

Two methods of labeling the air with smoke particles were employed in Operation Buster-Jangle: (1) JATO (jet-assist-take-off) units, which provided a column approximately 150 ft high, and (2) aerial "salutes" (fired from a 3-in. mortar), which burst from 100 to 350 ft above the ground (depending on the ballistics of the salute-mortar system employed). The Buster-Jangle results indicated that the aerial salute was the better method; however, one film of a JATO unit depicted the passage of the triple point through the cloud, thereby providing data on pressures in the free-air and Mach reflection regions. These results led to the decision on instrumentation for Tumbler-Snapper. Salutes were intended as the primary method, supplemented by JATO units in anticipation of determining the path of the triple point.

2.2 FEASIBILITY TEST OF HIGH-ALTITUDE MEASUREMENTS

As a feasibility test for Operation Ivy, a third method of labeling the air was introduced. This method consisted of firing white-phosphorus shells, fuzeed for air burst, from 90-mm

* $\frac{u}{c_0} = \frac{1}{\gamma} \frac{P}{P_0} \frac{1}{\sqrt{\frac{\gamma+1}{2\gamma} \cdot \frac{P}{P_0} + 1}}$

~~SECRET - INFORMATION~~

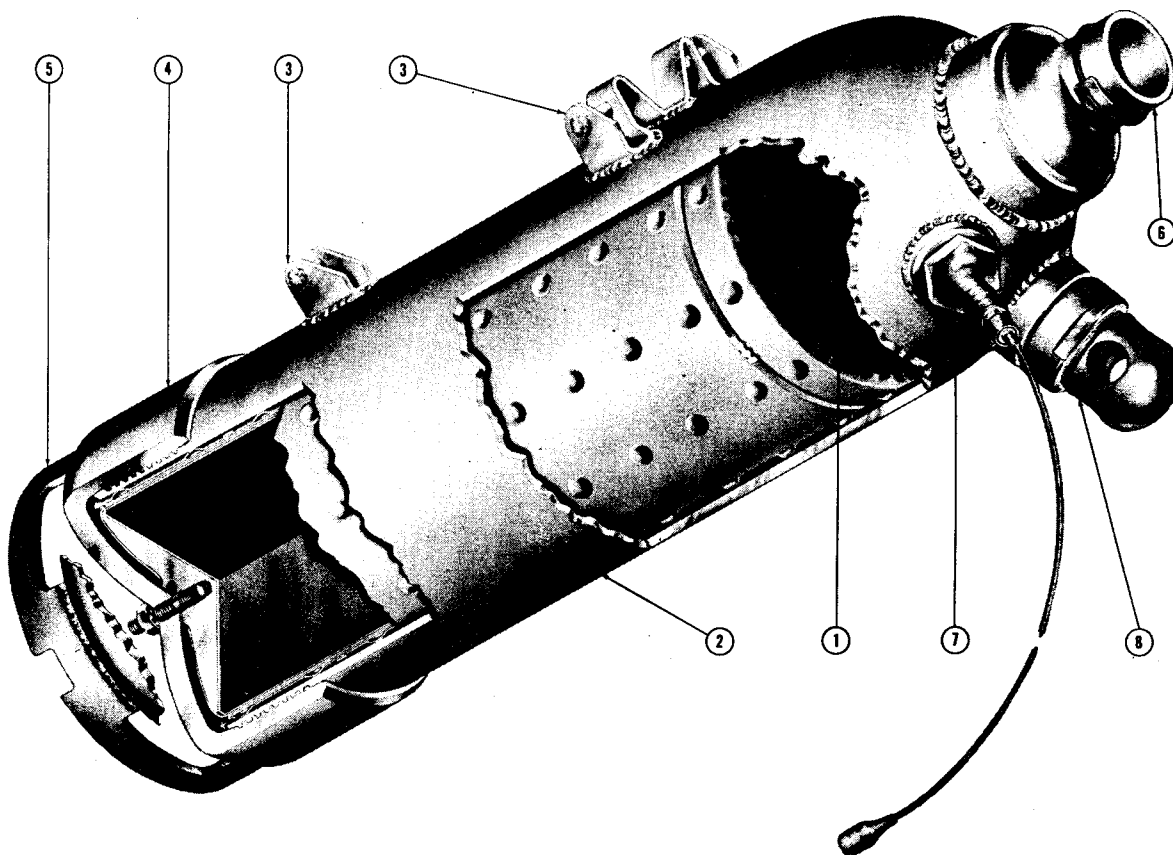


Fig. 2.1—JATO construction. 1, propellant cartridge. 2, chamber assembly. 3, attachment fittings. 4, forward closure cap. 5, ring-stand. 6, nozzle assembly. 7, igniter assembly. 8, safety pressure release assembly.

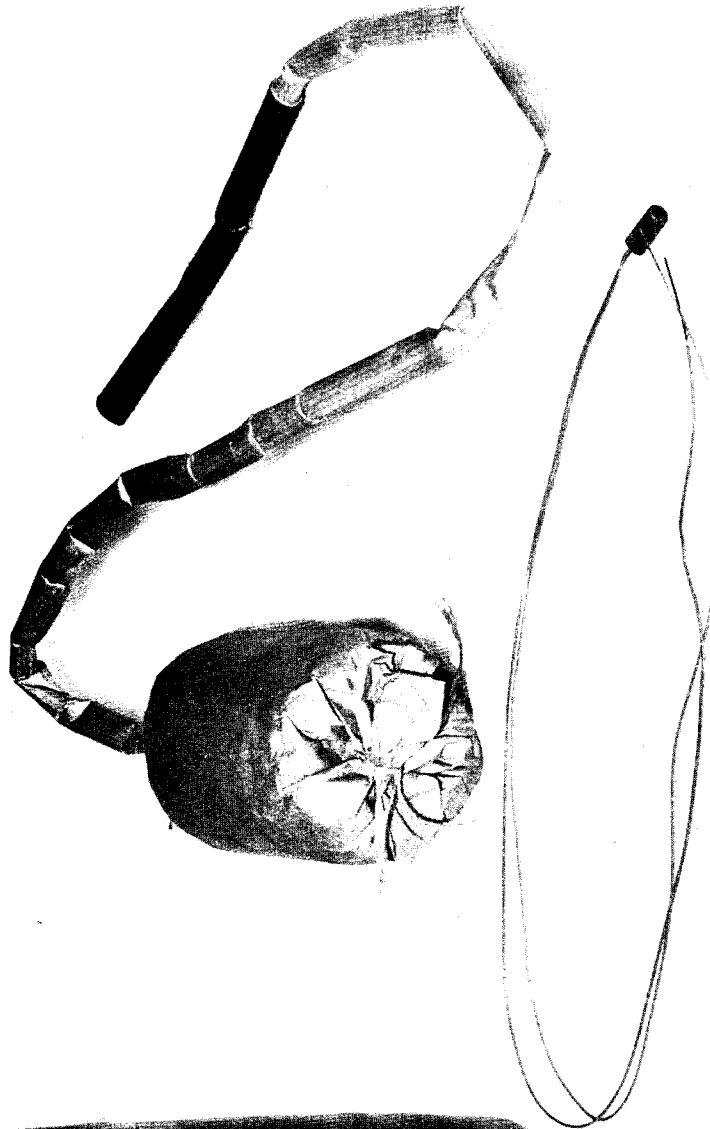
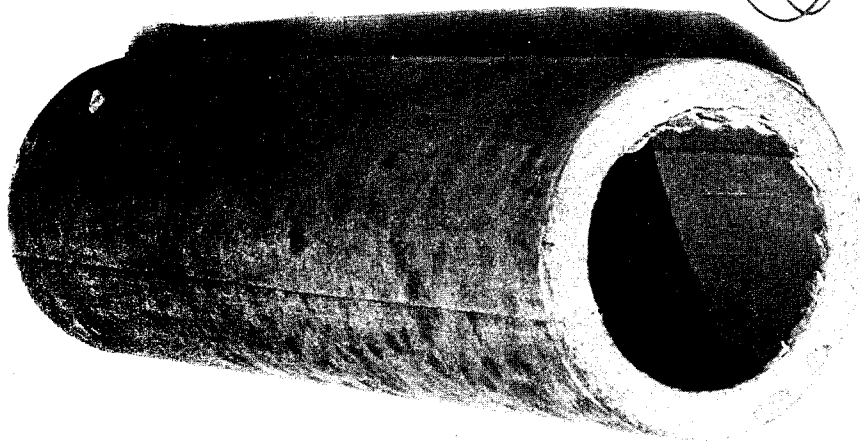


Fig. 2.2—Mortar, canister, and fuze: components.

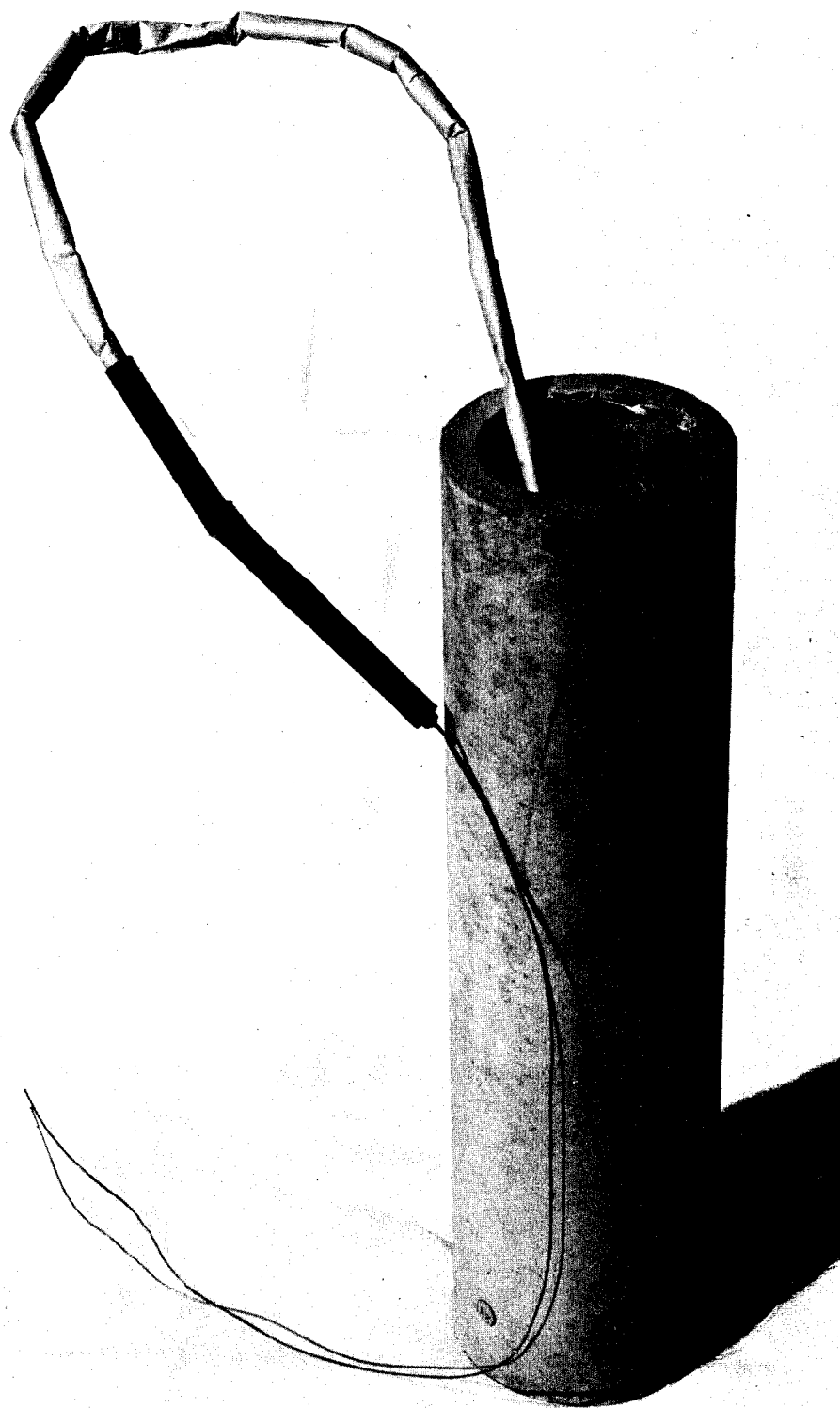


Fig. 2.3—Assembled mortar unit.

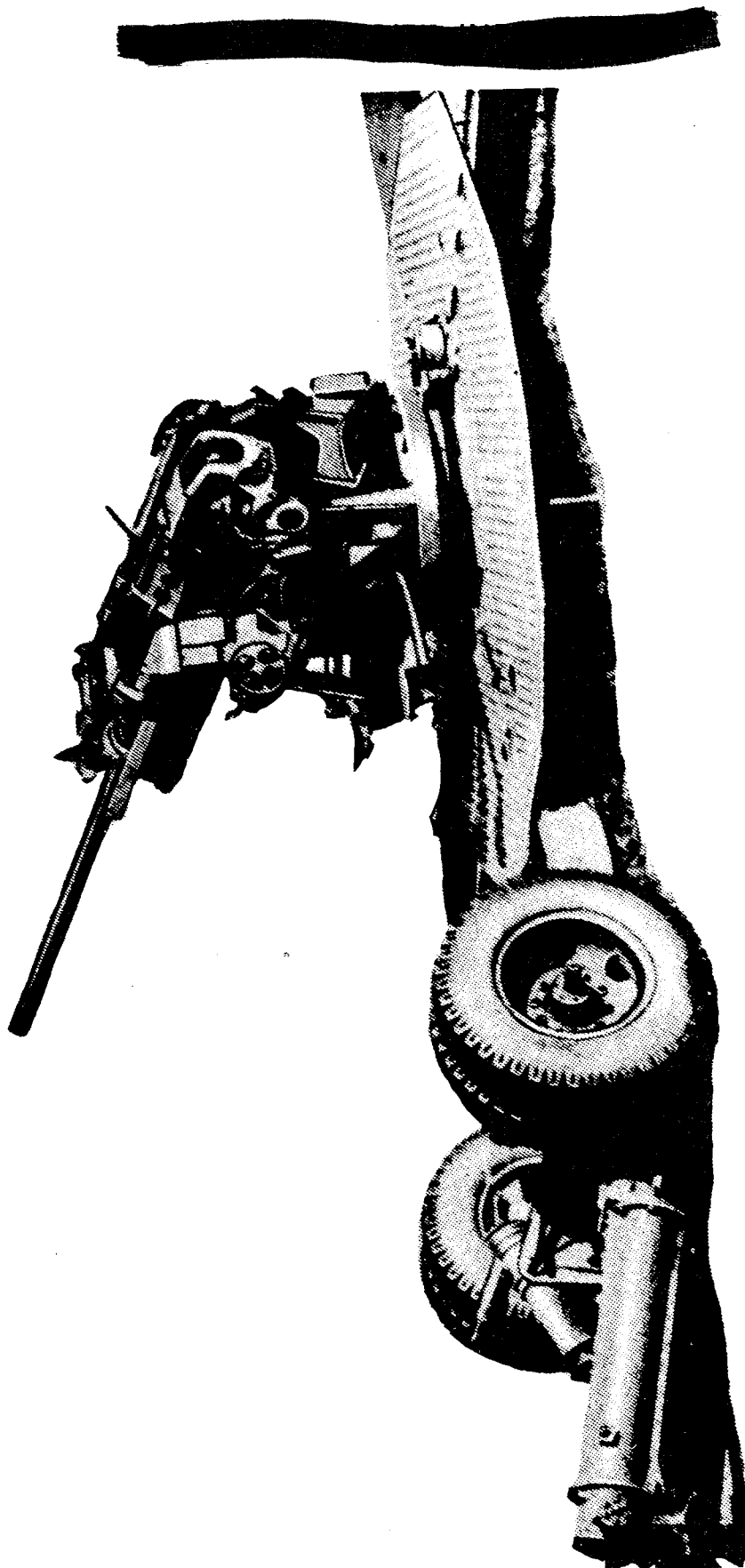


Fig. 2.4—90-mm antiaircraft gun.